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The Patent Office

Cardiff Road
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1. Your reference

378

2. Patent application number
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9905194.8

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

NEC TECHNOLOGIES (UK) LTD.
CASTLE FARM CAMPUS, PRIORSLEE
TELFORD, SHROPSHIRE TF2 9SA

Patents ADP number *(if you know it)*

7012313001

If the applicant is a corporate body, give the country/state of its incorporation

ENGLAND AND WALES

4. Title of the invention

SYNCHRONISATION IN DIGITAL DATA TRANSMISSION SYSTEMS

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

JAMES WHITE, PATENT OFFICER
NEC TECHNOLOGIES (UK) LTD.
THE IMPERIUM, IMPERIAL WAY
READING, BERKSHIRE RG2 0TD

Patents ADP number *(if you know it)* 7406028001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
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YES

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	8
Claim*(s)*	2
Abstract	
Drawing*(s)*	3

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	1
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. ~~I~~/We request the grant of a patent on the basis of this application.

Signature [signature] Date 4.3.99

12. Name and daytime telephone number of person to contact in the United Kingdom JAMES WHITE 0118 965 4606

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Synchronisation in Digital Data Transmission Systems

This invention relates to digital data transmission and in particular it relates to digital data decoders.

Reference is made to US patents 5 838 672 to Ranta and 5 479 444 to Malkamaki et al and "Mobile Radio Communications" published by John Wiley & Sons, Raymond Steele (Ed.) for a description of the prior art and technological background.

The following description is based on the GSM cellular communications system for which the invention is of particular utility. It will be apparent to those skilled in the art, however, that the invention may be applied to other systems of digital data transmission.

When a mobile phone terminal is to be used to communicate via a network, it must first obtain synchronisation with the network. This is essentially a three step passive process. The mobile terminal must synchronise with the base station transmission in time, then frequency and then must read control information to enable the location updating procedure. In the following description it is assumed that a channel containing a broadcast control channel (BCCH) has been chosen.

The prior art arrangements are shown in the flow chart of figure 1. Initially a Frequency Correction Burst (FCB), which is an unmodulated carrier, is sought by scanning of the wanted channel. When a FCB has been received

the burst is used to provide coarse time and frequency synchronisations e.g. by means of a narrowband filter. The coarse time and frequency synchronisations are applied to the next stage of the synchronisation process.

When a Synchronisation Burst (SB) is received it is processed and used to refine both time and frequency synchronisation. The SB contains channel coded information which enables the mobile terminal to access the network. After successfully decoding the SB the mobile terminal is fully synchronised to the network and communications can proceed.

The current arrangements for Synchronisation Burst equalisation are limited in performance by their intolerance to residual frequency offsets arising from the estimate of the frequency derived from the Frequency Burst. What this means in practice is that when a noisy estimate of the frequency offset is derived from the Frequency Burst processing, then the probability of successful decoding of the Synchronisation burst is significantly reduced. Under these conditions the mobile terminal is likely to fail to synchronise with the network.

Existing arrangements for Synchronisation Burst decoding are based on the conventional techniques of channel estimation, equalisation and convolutional decoding. The channel estimation technique used depends upon calculating the cross-correlation of the expected 64 symbol training sequence with the 64 symbol training sequence received in the synchronisation burst. This cross correlation gives an estimate of the

propagation channel. For a channel where no frequency error is present such existing arrangements provide a satisfactory channel estimate.

This is typically not the case, however, on a real fading channel when the mobile terminal is trying to gain initial synchronisation with the network. For a fading channel a residual frequency error is carried over from the imperfect frequency estimation derived by the initial Frequency Burst detection. A residual frequency error on the received symbols of the Synchronisation Burst is manifest as a constant, accumulating phase offset as a function of time.

This in turn affects the channel estimate obtained by performing a cross correlation of the received Synchronisation Burst symbols with the expected training sequence so as to cause a degradation of the equalisation procedure. When the bit error rate for the equalised burst exceeds that which can successfully be tolerated by the channel coding used to protect the information contained in the SB, then the synchronisation will fail.

According to the invention there is provided a channel estimation device for a digital telecommunication station in which a received training sequence is cross correlated with a selected subset of an expected training sequence to obtain a channel estimate and a frequency error estimate is derived from said channel estimate and the frequency error of the received burst is corrected in accordance with said frequency error estimate.

Examples of the invention will now be given with reference to the figures in which:

figure 1 is a flow diagram showing a prior art Synchronisation Burst decoder,

figure 2 is a flow diagram showing a Synchronisation Burst decoder according to the invention,

figure 3 is a Doppler tracking phase locked loop,

figure 4 shows a GSM Synchronisation Burst training sequence

A means for an improvement over the prior art methods in the tolerance to residual frequency error of the Synchronisation Burst decoding process is illustrated in the flow diagram of figure 2. The frequency burst detection **1** and coarse time and frequency estimates **2** are obtained in the usual manner in accordance with prior art methods.

A GSM training sequence is shown in figure 4 with each of the symbols labelled 1 to 64. It is convenient here to show the training sequence as comprising three sections labelled **A** , **B** and **C** . The full sequence of symbols from 1 to 64 is transmitted consecutively, however, and figure 4 serves to illustrate as section **B** the 24 symbol sub set used to obtain the frequency error estimate. The symbols 1 through 64 would be the training sequence expected to be received by the mobile phone terminal.

Returning to figure 2, at capture of the synchronisation burst **3** the received training sequence is cross correlated with the subset **B** of the expected training sequence. This cross correlation makes use of the auto correlation property of a subset **B** of the Synchronisation Burst training sequence. Although this 24 symbol sequence is not perfectly auto correlated, it is almost so.

Therefore the cross correlation of the received symbols is performed using the 24 symbol subset **B** of the training sequence. This cross correlation provides a channel estimate which has been generated from a more temporally localised sequence of received symbols. The effects arising from the phase error due to a residual frequency offset are therefore reduced and the channel estimate is better than it would have been had the full 64 symbols of the training sequence been used.

The next step **4** is to obtain a frequency error estimate using the 24 symbol based channel estimate in conjunction with the *a priori* 64 symbol training sequence. This can be achieved by using a standard technique such as a second order phase locked loop (PLL), locked in frequency and phase to the reference (expected) training sequence symbols. A block diagram of a suitable PLL is shown in figure 3.

The Doppler Tracking PLL of figure 3 in the equaliser is of the decision directed 2nd order type. This provides a PLL which is locked in both phase and frequency to the reference symbols. The PLL provides a phase correction to the next received symbol to be equalised.

The characteristic equations describing the PLL are:

$$\phi(n-1) = \phi(n-2) + f(n-1) + k_1\theta(n-1)$$
$$f(n-1) = f(n-2) + k_2\theta(n-1)$$

where k_1 is the 'phase' loop gain and k_2 is the 'frequency' loop gain. The open loop transfer function is given by:

$$\frac{\Phi(z)}{\Theta(z)} = \frac{k_2}{1-2z^{-1}+z^{-2}} + \frac{k_1}{1-z^{-1}}$$

The values

$$k_1 = 0.08$$
$$k_2 = 0.08 / 29.0$$

for the loop gains k_1 and k_2, were determined by trial and error using a Matlab model, where the main criterion used was the convergence of the loop within the available number of symbols in a Normal Burst.

In this example, for Normal Burst equalisation the PLL is used solely for phase correction during equalisation. For Synchronisation Bursts, however, the PLL is used in addition for performing an initial frequency estimate from the training sequence. This initial frequency estimate is then used to apply a frequency correction to the set of received symbols before equalisation proper is performed.

After application of the chosen frequency estimate algorithm the resultant frequency estimate is then used to correct all symbols of the received burst. The performance of the frequency estimate algorithm must exceed the performance of the FCB frequency estimation algorithm so that the applied correction will improve the residual frequency error present in the corrected received symbols. After the frequency correction has been applied to the whole buffer of received symbols a second channel estimate is calculated at **5**.

This second channel estimate is made by taking the cross correlation of the 64 frequency corrected symbols of the received training sequence and the 64 symbols of the expected training sequence of the Synchronisation Burst. This channel estimate should therefore be better than the 24 symbol channel estimate previously calculated and better also than the 64 symbol channel prior art estimate usually obtained. This is due to the reduction of residual frequency error and use of all the symbols of the training sequence in the cross correlation. Equalisation of the received SB then proceeds in the usual manner through **6** and **7** using the frequency corrected symbols.

Proposals exist for varying or adapting training sequences e.g. as described in US 5 479 444, US 5 838 672 and WO 9807291. A selected subset of an adaptive training sequence may be used for cross correlation with an expected training sequence to provide an initial estimate of frequency error for correction of the frequency of the received burst in accordance with the initial estimate of the frequency error.

A training sequence may also be adapted to provide a subset of the training sequence with improved auto correlation properties.

CLAIMS

1. A channel estimation device for a digital telecommunication station in which a received training sequence is cross correlated with a selected subset of an expected training sequence to obtain a channel estimate and a frequency error estimate is derived from said channel estimate and the frequency error of the received burst is corrected in accordance with said frequency error estimate

2. A channel estimation device as in claim 1 in which the received training sequence is part of the signal within a synchronisation burst transmitted by a base station of a cellular telephone network.

3. A channel estimation device as in claim 2 in which the received training sequence is the 64 bit training sequence of the GSM system

4. A channel estimation device as in claim 3 in which the selected subset comprises the 21st through to the 44th symbols of the training sequence.

6. A channel estimation device as in claims 1 or 2 in which the training sequence is an adaptive training sequence.

7. A channel estimation device as in claim 1, 2 or 6 in which the selected subset is an adaptive subset

8. A channel estimation device as in any preceding claim in which the frequency error estimate is obtained by a Doppler tracking phase locked loop.

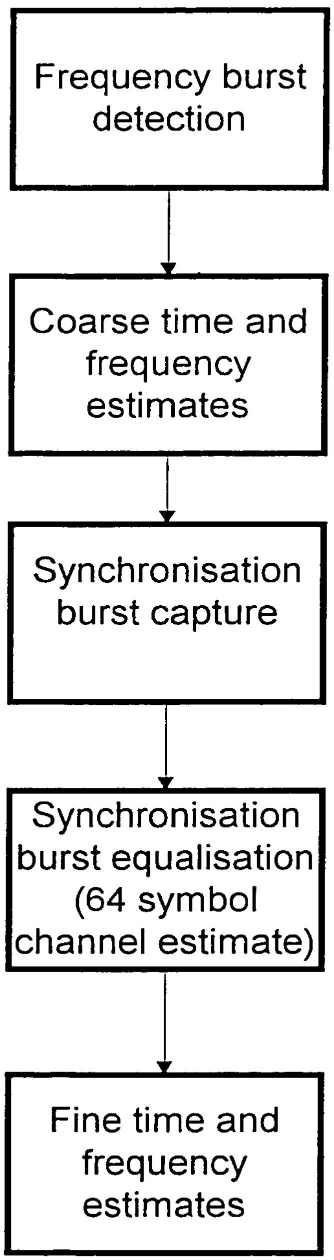


Figure 1

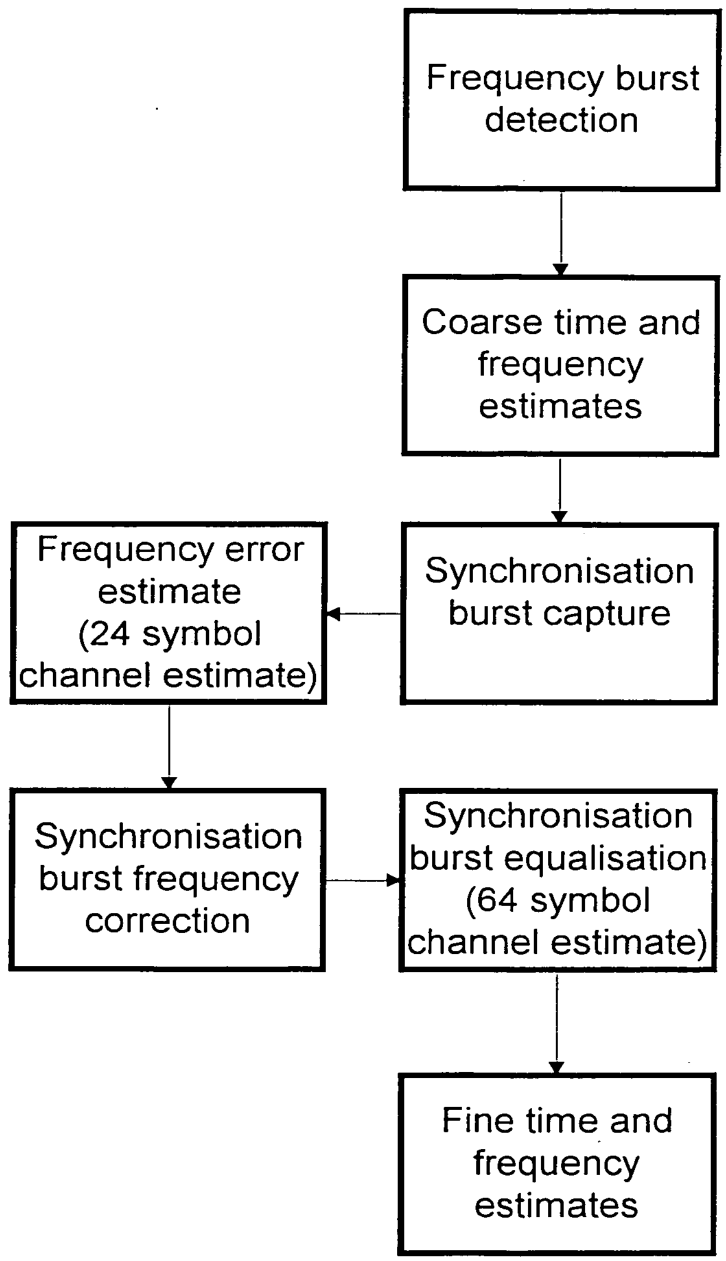
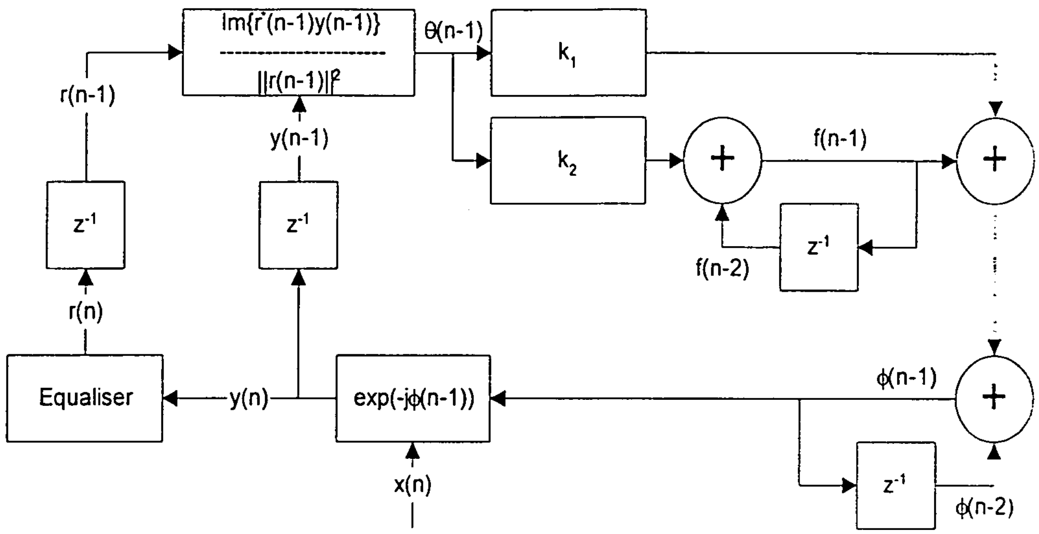


Figure 2


Im{r*(n-1)y(n-1)}

||r(n-1)||²
θ(n-1)
k1
k2
r(n-1)
y(n-1)
f(n-1)
f(n-2)
z-1
z-1
z-1
z-1
r(n)
Equaliser
y(n)
exp(-jϕ(n-1))
ϕ(n-1)
x(n)
ϕ(n-2)

Figure 3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	1	1	1	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0

A

21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
0	1	0	0	0	0	0	0	1	1	1	1	0	0	1	0	1	1	0	1	0	1	0	0

B

45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
0	1	0	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0	1	1

C

Figure 4